



Grazing-Incidence EUV Collector Coated by DLC

Sho Amano, Tomoaki Inoue, and Tetsuo Harada

Laboratory of Advanced Science and Technology for Industry, University of Hyogo, 3-1-2 Kouto, Kamigori, Ako-gun, Hyogo 678-1205, Japan
E-mail; sho@lasti.u-hyogo.ac.jp

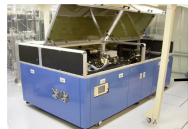
Plasma-debris damages a EUV-collection-mirror and degrades its reflectivity. This is a critical issue for most of plasma EUV sources and its mitigation is required.

In this paper, we propose a new approach to mitigate the debris effects. In generally, the plasma-debris occurs deposition and/or sputtering on the mirror surface, but the latter is more serious. Our idea is to use a **sputtering-resistant mirror with a very hard coat** for grazing-incidence EUV collectors. For this hard coat, new diamond-like carbon (DLC) film is proposed.

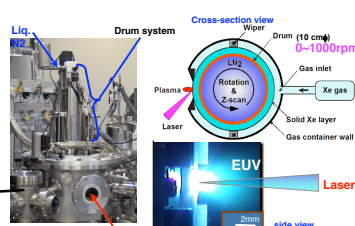
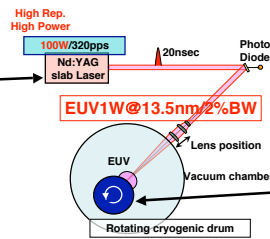
The DLC film formed by Ar cluster ion beam assisted deposition, which was developed in our laboratory (LASTI), has the high hardness of 50GPa.

To evaluate the DLC coating as EUV mirror, we measured 1) its **reflectivity** by using our SR(Synchrotron Radiation) facility "NewSUBARU", 2) its **focusing performance** of the cylindrical mirror and 3) its **erosion rate** (compared with Ru coating) by using our **Xe - LPP source**.

Solid Xe target - LPP EUV Source



performance	
average power	230W
pulse rep. rate	320pps
pulse energy	0.7J
pulse width	2.8ns
transverse mode	M ² ₂₃ 1.5
longitudinal mode	single
table size	1.2 x 2.4m



Performance

EUV @13.5nm/2%BW

- 1) CE ; 0.9%/2πsr
- 2) 1 W continuous generation

Ref.) S.Amano et al, Appl.Phys.B.vol.101,213(2010).

Debris

Major component ; fast ions (<6keV)

Ref.) S.Amano et al, Rev.Sci.Inst.,vol.81,023104(2010).

Ref.) S.Amano et al.,IEEE J. QE-37,296(2001).

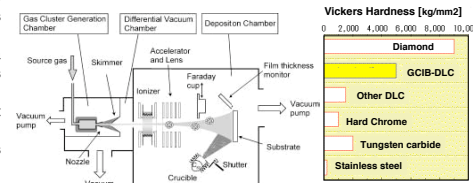
Ref.) S.Amano et al, Rev.Sci.Inst.,vol.77,063114(2006).

GCIB-DLC (High Hardness film)

Diamond-like carbon (DLC) films with **high hardness** were developed in our laboratory (LASTI), which formed by Ar gas cluster ion beam (GCIB) assisted deposition.

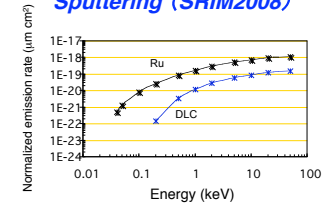
The deposition was performed with the evaporation of C₆₀ as a carbon source during the irradiation of Ar cluster ion beam. This is useful to form hard DLC films, as the bombardments induced high-pressure and high-temperature effects at the impact surface, and ultra low energy effects.

The hardness of **50GPa** was obtained. This value was approximately two times higher than that of films deposited with conventional methods.



Vickers Hardness [kg/mm ²]
0 2,000 4,000 6,000 8,000 10,000
Diamond
GCIB-DLC
Other DLC
Hard Chrome
Tungsten carbide
Stainless steel

Erosion rate calculated for Xe ion Sputtering (SRIM2008)



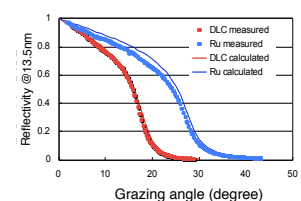
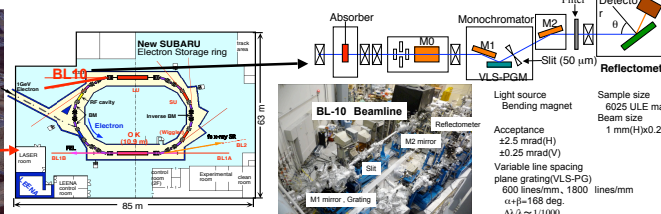
The erosion rate at the DLC were 1~3 order of magnitude less than that at Ru.

A sputtering-resistant mirror at the DLC.

Reflectivity measurement by SR (NewSUBARU)



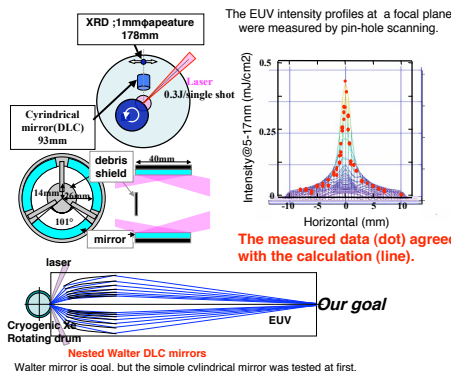
NewSUBARU building in the Spring-8 site



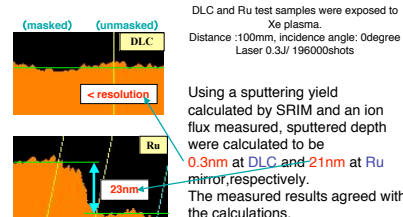
Critical angle@13.5nm
DLC ; 17.9 deg Ru ; 27.5 deg

The measured reflectivities agreed with the calculations.

Focusing test by cylindrical DLC mirror

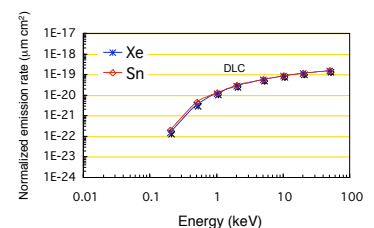


Measurement of depth sputtered by Xe plasma (AFM)



The erosion rate by Xe ions for the DLC coating was an order of magnitude less than that for the Ru coating.

Erosion rate calculated for Sn ion sputtering (SRIM2008)



The erosion rate by Sn ions was same as by Xe ions.

In the test of mirror reflectivity and focusing for the new DLC coating with the high hardness, the measured results were in good agreement with the calculations. These indicate the DLC coating can be used for EUV mirror. The measured erosion rate by Xe ions for the DLC coating was an order of magnitude less than that for the Ru coating. The SRIM code calculation showed that the erosion rate by Sn ions was same as by Xe ions. We conclude that the **hard DLC mirror** is useful as a **sputtering-resistant mirror** for not only Xe but also Sn - LPP source.